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# Late glacial river-bed changes on the Little Hungarian Plain, based on preliminary chronological, geological and paleontological data

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**Abstract:** Comprehensive chronological, geological and paleontological investigations were conducted as part of archaeological excavations in 2011 and 2012, prior to the construction of the M85 motorway between Győr and Csorna, Hungary. These studies clearly show that the alluvial fan that underlies much of the Little Hungarian Plain was built up by streams flowing in a southeasterly to northwesterly direction from the nearby Bakony Hills, and continued to form until the end of the last glacial period. The northern part of the fan, now named the Csorna Plain, became inactive (i.e. became a fossil river-bed system) at about 25–15 ka, when the Rába and Marcal rivers changed their flow direction from south–north to west–east. As a result of this change in flow direction, the Rába and Marcal rivers became incised, capturing the Bakony stream beds, stopping sediment deposition on the northern side of the alluvial fan (essentially the left bank of the Rába-Marcal river system), although the southern part of the fan continue to form as before. On the northern side of the fan, the sediment surface dried out due to falling groundwater levels, and aeolian sand-drifts began to form. Eventually, accumulation of the sand-drift sediments ceased due to the deposition of loess-type sediments, which fixed the surface, conserved the sand-drift shapes, and contributed to the straightening and eventual canalization of the fluvial channels. Geoarchaeological examinations indicate that the development of present fluvial features were strongly affected by the settlement and tillage activity of human communities on the Csorna Plain.

**Keywords:** Little Hungarian Plain; river capture; Csorna Plain; fossil river-bed

## 1 Introduction

The authors carried out comprehensive paleoenvironmental research on the Csorna Plain as part of archaeological excavations that took place along the M85 motorway between Győr and Csorna in northwestern Hungary (Figure 1) in 2011 and 2012 [1, 2]. Prior to the excavation, historical maps and landscapes of the study area were analysed to provide a basis for comprehensive field-based geomorphologic examinations. These studies extended throughout the river valley and over both banks of the recent Rába River, leading to the development of a new paleohydrological model detailing the development of the area's fluvial system; the preliminary results of this modelling work are introduced in this paper. In the last 30–40 years, several articles have been published in the Hungarian geographical literature relating to the physical geography and river-bed development of this area [3–11]. Nevertheless, after careful examination, these publications could all be traced back to a single illustration of river-bed development presented in a publication by József Sümeghy (Figure 2) [14]. According to Sümeghy, neotectonic processes controlled fluvial system development by forming rapidly sinking sub-basins, both on the Great Hungarian Plain and Little Hungarian Plain [12, 13]. These sub-basins formed the bottom-most parts of the aforementioned basins and influenced both river-bed movement and river-valley evolution [14–23]. Based on our studies, a comprehensive geological model was developed for the Great Hungarian Plain, with only a hypothetical sketch diagram made for the evolution of the southern part of the Little Hungarian Plain [11].

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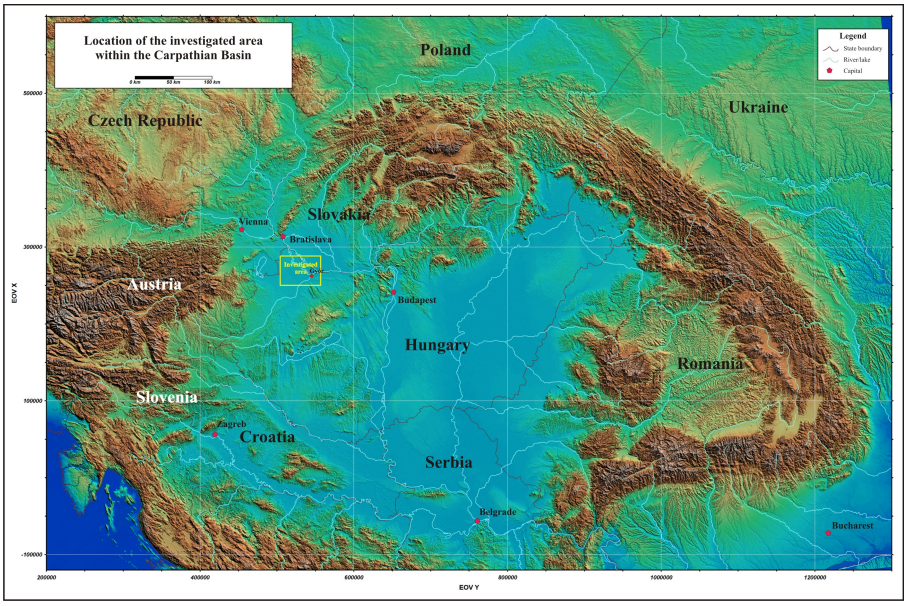


**Figure 1:** Location of the study area, marked by a yellow rectangle, within the Carpathian Basin; base map altered from [37].


**Figure 2:** Figure illustrating the mosaic-like neotectonic structure of the Carpathian Basin, as seen in 2D (left) and 3D (right) [14]. Red circles highlight the study area; abbreviations: 9=Little Hungarian Plain, 10=Pannonhalma cone, 11=Csallóköz depression.

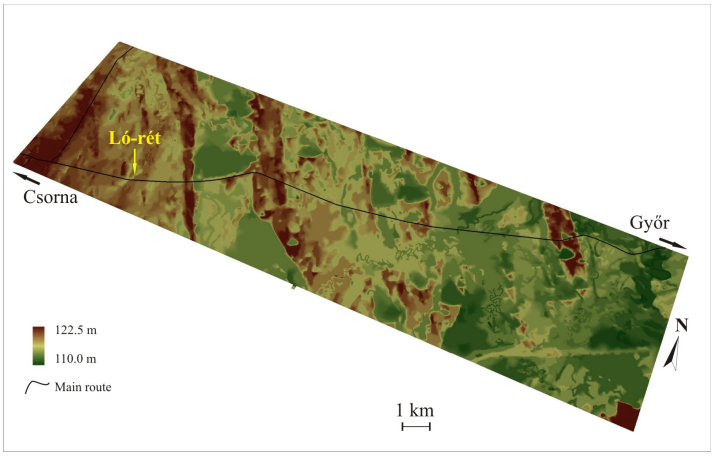


**Figure 3:** Digital topographic model of the study area, showing the recent geomorphology and relief

## 2 Material and methods

This research is based on the following data: a 30 km long and 70–140 m wide archaeological profile intersecting several Quaternary units; shallow core samples obtained during geoarchaeological drilling [1, 2]; historical topographic maps (e.g. Austrian military maps); digital topographic models of the area (Figure 3); landscape images taken from several heights; and sediment isopach maps based on previous geological drilling data [24–35]. The original aim of the study was to obtain a geomorphic view of archaeological culture and settlement, but the results obtained also provided new information on the development of hydrologic systems in the region, as presented here.

## 3 Results

Two sediment accumulation peaks (depocentres) are clearly observable on the isopach maps, contrary to previous studies which had indicated a single depocentre (Figure 4). Currently, the Danube River flows in a northwest to southeast direction, with its tributaries (the Rába, Rábca, Répce and Marcal rivers) running from southwest to northeast. However, streams in the Bakony Hills near Győr originally had different flow directions, as seen in a series of southeast–northwest oriented river beds observed during the archaeological excavations on the Rába River's left bank. This inactive, deserted, choked fossil river-bed series, which is found between Csorna and Győr, was probably the former continuation of the present southeast–northwesterly flowing Bakony Hills streams (the Gerence, Csikvándi-ér, Csángota-ér, Sokoró-ér, and Pándzsa streams), isolated by the Rába-Marcal river system. Thus,ancient versions of the recently active streambeds seen on the right bank of the Rába-Marcal river system (abbreviated here as the R/M system) can be seen on the river's left bank. This idea is supported by local morphology and landscape data, and using the historical maps. As the beds seen on the right bank of the R/M system have also been found on the left bank, all the streams in the Bakony and R/M systems originally flowed uniformally to the northwest, towards the deepest depocentres on the Little Hungarian Plain (Figure 5). This phenomenon is also obseved on the Great Hungarian Plain [12, 38–40].

Therefore, the fossil river-bed system seen on the Csorna Plain does not reflect bed switching of the Rába River [11], but rather shows similarities to beds formed by a set of contemporaneous and parallel glacial streams and rivers from a different source area. At the end of the glacial period, the flow direction of the Répce, Rábca and R/M rivers had changed from a southeast–northwest to a west–east orientation, due either to northwesterly–southeasterly extension of the Danube Fan or some other neotectonic event in the region [12, 13, 38–40]. The fan plain, which extended from the Bakony Hills to the centre of Little Hungarian Plain, was split in half as a result of this neotectonic activity (Figure 6).

This abrupt change in flow direction on the R/M river system captured the beds of the Bakony streams, so that the right bank, near to the Bakony Hills, remained an active, extending fan, whereas the left bank became isolated and dry. Further development of the fossil fan thereafter was dependant on the amount of alluvial sediment carried into the area by the R/M system during floods. Once active geomorphological development had ended in these parts of the fan, the main geological processes included

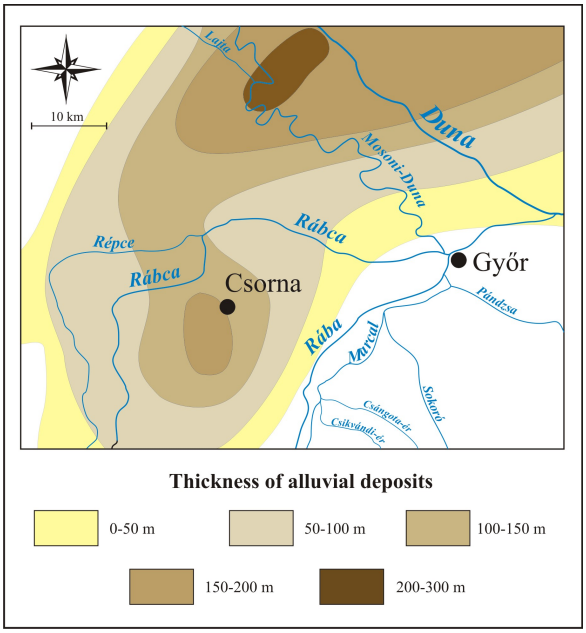


**Figure 4:** Map showing the thickness of alluvial deposits in the study region, based on examination of wildcat wells on the Little Hungarian Plain [25], and recent river beds.

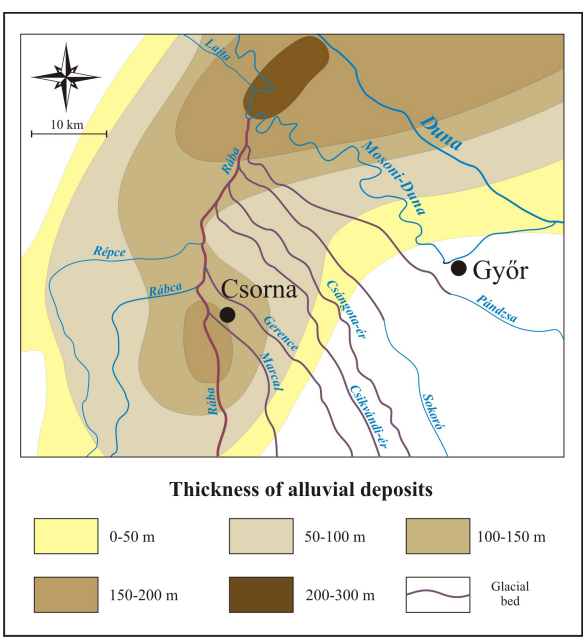


**Figure 5:** Flow directions of the Danube River and its feeders during the Late Pleistocene.

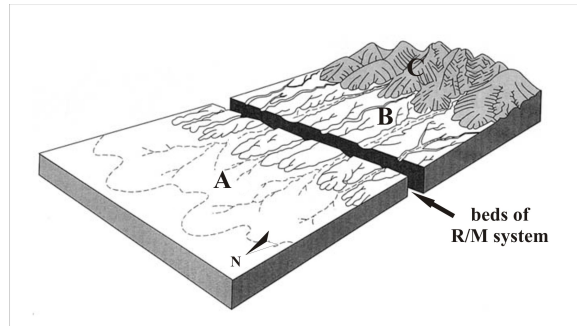


**Figure 6:** Incision of Rába-Marcal river system into the alluvial fan formed by streams of the Bakony Hills region; where A= drying part of the fan (Csorna Plain), B = active, developing part of the fan, and C= Bakony Hills.

straightening of the fluvial features (such as natural levees, marshes and river beds), accumulation of R/M river system (alluvial) deposits, and soil formation.

The development of the river system on the Little Hungarian Plain was particularly influenced by changes in sediment transport directions and the accumulation of Quaternary sediments, and the timing of stream-bed capture is important because vegetation cover and physical and chemical weathering conditions have changed remarkably in the area during the last 20000–30000 years. Thus, the transformation age of the paleohydrologic system also determines the environmental background of fluvial system development. Determining the age of stream capture was achieved through geological and paleontological study of drill core from the area, and by analysing geological profiles observed during archaeological excavations. As part of these studies, a glacial stream-bed, and natural levee and marsh system was identified at the Ló-rét archaeological site near Csorna, which had been formed by a series of rivers running from the Bakony Hills towards the Csorna Plain (Figure 7); evidence of Holocene sediment accumulation within the R/M river system was also uncovered in the area. As active river accumulation was evident earlier than 15000 years BP, based on radiocarbon dating results, the alluvial fan developed by the Bakony Hills stream-beds probably became inactive at the end of the glacial period; specifically, the capture of these beds by the R/M system appears to have occurred during the last phase of the glacial period. This idea is supported by sedimentological study of drill core obtained during the archaeological excavation; these results suggest that the surface of the inactive fan was changed by depositing aeolian sediments (loess) on top of alluvial sediments (windblown sand) (Figure 8).

Based on both the sedimentological and radiocarbon evidence, the following development model has been

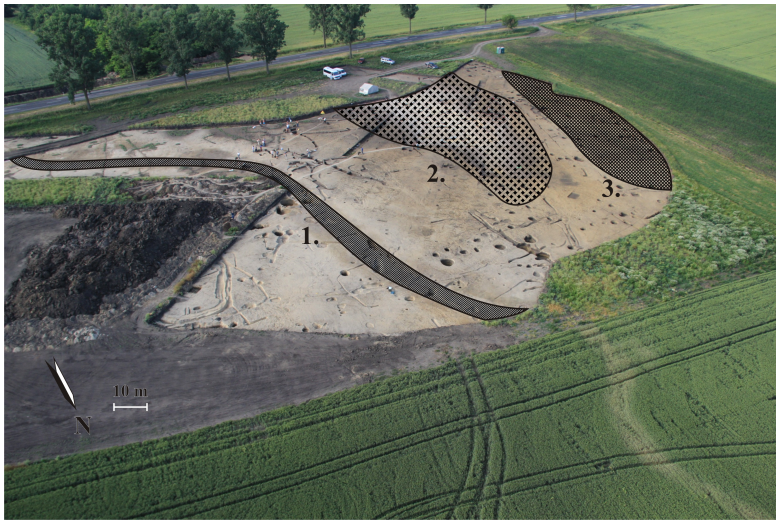


**Figure 7:** Aerial photo showing the Ló-rét archaeological site near Csorna; 1. fossil bed, 2. natural levee (former settlement), 3. marsh.

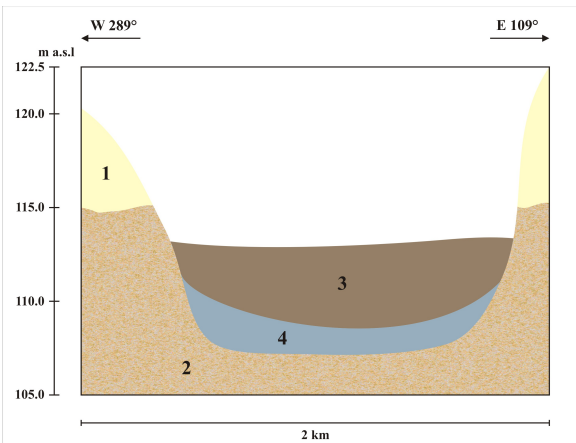


**Figure 8:** Cross section of a ripple mark observed near the Ló-rét archaeological site; 1. aeolian loess deposits, 2. sandy bedrock, 3. clayey loam, 4. lacustrine sediment.

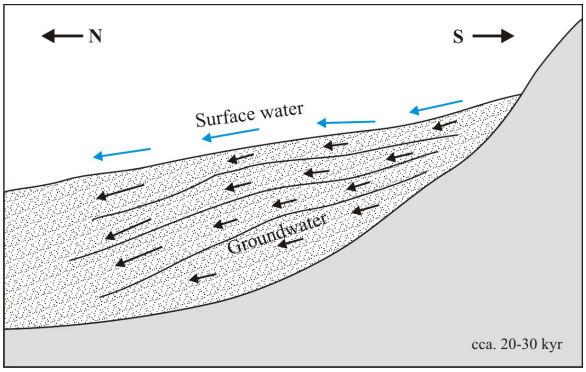


**Figure 9:** Sketch of the alluvial fan formed by the Bakony streams during the Late Pleistocene; grey areas = bedrock, stippled areas = alluvial fan, black arrows = groundwater flow direction, blue arrows = surface water (i.e. Bakony streams) flow direction.

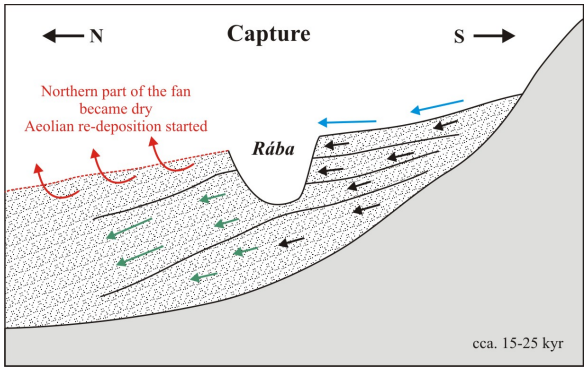


**Figure 10:** Sketch illustrating changing paleohydrologic conditions following bed capture of the Bakony Hills streams by the Rába-Marcal river system during the Late Pleistocene; grey areas = bedrock, stipled areas = alluvial fan, black arrows = groundwater flow direction, blue arrows = surface water (i.e. Bakony streams) flow direction, green arrows = areas of reduced groundwater flow.

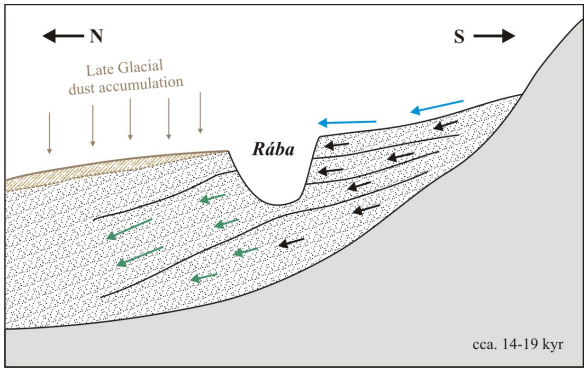


**Figure 11:** Process of dust accumulation and sand surface fixation at the end of the Pleistocene; grey areas = bedrock, stipled areas = alluvial fan, black arrows = groundwater flow direction, blue arrows = surface water (i.e. Bakony streams) flow direction, green arrows = areas of reduced groundwater flow.

constructed for the region. During the last period of the Glacial, probably between 30000 and 20000 years BP, alluvial fan deposits were deposited on the Csorna Plain by streams flowing to the northwest, towards to the centre of the Little Hungarian Plain (Figure 9).

Between 25000 and 15000 years BP, a change in the flow direction of the R/M river system caused west–easterly incision of this system and stream-bed capture of a set of streams previously flowing into the plain from the Bakony Hills. This change in turn radically changed the superficial paleohydrologic conditions and underground water-flow conditions in this area (Figure 10). As a result of stream-bed capture and river-bed incision, the surface and near-surface of the fan dried out and autochthonous aeolian redeposition of sandy sediments began. This process resulted in the development of wind-blown sand layers and related morphological forms ranging from thin sand-veils up to sand hills many metres tall [36].

Following this period of aeolian redeposition and sand-drift development, aeolian dust began to accumulate in the study area, developing typical loess layers (Figure 11). The loess layers, on average one metre thick, were deposited at the end of the upper Weichselian, between 19000 and 14000 years BP, in the cold periods of the Late Glacial period. Therefore, sand drift development ended during the Late Glacial, as the aeolian loess layers restrained the movement of the sand drifts and formed a cover horizon that stabilized and fixed the sand forms on the alluvial fan surface.

In summary, the history of the Csorna Plain to the end of the Glacial Period consisted of the following events: alluvial accumulation of the fan, bed-capture by the Rába and Marcal Rivers, subsequent division of the fan into active and inactive parts, and finally the aeolian transformation and stabilization of the inactive portion of the fan.

## 4 Summary

Comprehensive geological and paleontological studies conducted in connection with archaeological excavations on the Csorna Plain, between Győr and Csorna, aimed to examination the glacial river fan situated on the southern part of the Little Hungarian Plain. These studies provided evidence that this fan was deposited by means of a southeasterly–northwesterly oriented series of parallel stream beds flowing from the Bakony Hills towards depocentres in the centre of the Little Hungarian Plain. Between 25000 and 15000 years BP, the flow direction of the nearby R/M river system shifted from a south-to-north to west-to-east direction, capturing the beds of the Bakony region streams, splitting the alluvial fan into two halves and causing the northern part of the fan, located on the Csorna Plain, to become inactive. The change in river flow directions may have been caused by changing neotectonic conditions [12, 13, 38–40], and/or climatic changes [41].

Although fluvial sediment deposition continued normally on the Bakony Hills (southern) side of the alluvial fan, in the inactive (northern) part of the fan, the end of deposition caused groundwater levels to fall, drying out the sediment surface. This was followed initially by a period of sand-drift development on the Csorna Plain, which continued until the end of the Glacial Period, when dust accumulation and aeolian loess deposition fixed the sand-drift forms in place. Straightening of fluvial sediments (such as river-bed, natural levee, and marsh deposits) began on the Csorna Plain soon after the bed capture of the Bakony streams in the Holocene; this process continued in the involved area until overtaken by anthropogenic channelling/irrigating processes. On the basis of the geoarchaeological examinations conducted, the modern alluvial forms seen in the area were strongly influenced by the habitation and cultivation processes of human communities on the Csorna Plain.

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